ELECTRONICS

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ELECTRONICS

By Douglas M. Bonham
Heath Company

1981 Printing
of the 1977 Revision

BOY SCOUTS OF AMERICA
IRVING, TEXAS

Requirements

1. Do the following:
   a. Draw a simple schematic diagram. It must show resistors, capacitors, and transistors or integrated circuits. Use correct symbols. Label all parts.
   b. Tell the purpose of each part.
2. Do the following:
   a. Show the right way to solder and unsolder.
   b. Show how to avoid heat damage to parts.
   c. Tell about the function of a printed circuit board. Tell what precautions should be observed when soldering them.
3. Select ONE of the following:
   a. Tell how you can use electronics for a control purpose. Build a circuit to show this.
   b. Tell about the basic principles of digital techniques. Show how to change three decimal numbers into binary numbers. Show how to change three binary numbers into decimal numbers. Build a circuit to show digital techniques.
   c. Tell about three audio applications of electronics. Build a circuit to show audio techniques.
4. Do the following for the project you built in requirement 3:
   a. Show how to read the schematic diagram of the project.
   b. Show how the project works. To the best of your ability, tell how it operates.
5. Do the following:
   a. Show how to solve a simple problem involving current, voltage, and resistance using Ohm's law.
   b. Tell about the need for and the use of test equipment in electronics. Name three types of test equipment. Tell how they operate.
   c. Tell about three jobs in electronics. Tell what training is needed for each job.

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Contents

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How To Earn the Electronics Merit Badge

Your first step should be to meet your Electronics merit badge counselor. You should discuss the requirements with him as soon as possible. His advice and guidance can be very valuable.

To meet requirement 1, choose one of the schematic diagrams that are shown in the project sections of this booklet. Using a pencil, copy the diagram exactly as it is shown. Note the different types of components used. Look up the components in the schematics chapter to learn what they are used for.

Show your drawing to your counselor. Point out the things you have learned. If he is satisfied, you have passed requirement 1.

Before attempting requirement 2, you should carefully study the chapter on soldering. Practice soldering and unsoldering wires. When you feel you are ready, show your skill to the counselor. Be prepared to discuss soldering precautions, printed circuit boards, and heat damage to components.

Requirement 3 is the most demanding, but it is also the most fun. Here you will actually build a working electronic device of some kind. Several kit and "scratch" projects are recommended. Choose your project carefully. Make sure you can find all the required parts before making your purchase. Also consider what tools are required and the usefulness of the end product. You may choose a project other than those listed. However, you should check with your counselor to make sure that the project is suitable.

After you build your project, show it to your counselor. Explain how it works and show your ability to read the schematic diagram.

As your final requirement, you will be asked to solve a simple problem using Ohm's law. This law and several sample problems are discussed later. You should also be able to discuss electronic test equipment and jobs in electronics.

Figure 1

Tools for Electronics

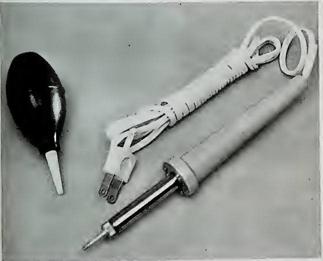


Figure 2

The basic tools for most of your electronics work are shown in Figure 1. You should get these tools together before you begin your electronics work. Most likely you will find these in your dad's workshop.

A good electric soldering iron is necessary in electronics work. Don't use a soldering gun. (The reasons will be discussed later.) You can buy a small soldering iron at your neighborhood hardware store. Get a small one with interchangeable tips. They are not expensive. See Figure 2.

A pair of long-nosed pliers is a necessity for your work. You will use these for holding wires or parts while you solder. A pair of diagonal cutting pliers is also necessary.

Wire strippers are used for removing the insulation from wires before soldering. A small flat-blade screwdriver is required for tightening screws.

For most of the "from scratch" projects, you will also need a drill of some kind for cutting holes for switches.

Other Equipment

On most projects, any small-diameter solid or stranded hookup wire can be used. However, on some projects, very small wire may be necessary.

Selecting the proper solder is easy. Only 60/40 rosin-core solder should be used. The solder should be clearly marked "for electronic use." Under no circumstances should you use acid core solder for electronics work.

Most electronic parts stores have a selection of perforated boards specially made for wiring electronic projects, shown in Figure 3. Many come with small clips for mounting electronic parts. These boards are ideal for constructing simple circuits.

If your dad has a workbench that you can use, fine. A card table is also satisfactory. However, cover it with cardboard to prevent damage to the surface. You will also need a few small boxes or jars to hold the parts.

Buying Parts

Most electronic parts stores have the components you will need for

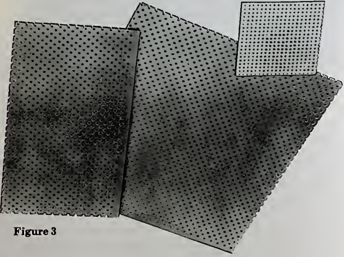


Figure 3

Figure 4

your project. If you choose a "scratch" project, you will have to buy the parts separately.

Generally, it is easier to buy a complete project in kit form. A kit has several advantages. First, it ean be bought or ordered as a single package. All necessary parts are supplied, including wire and solder. Second, detailed assembly instructions are included. This makes the project easier to assemble. Third, special parts such as printed circuit boards are provided with the kit. Such parts are difficult and expensive to make. Fewer tools are required since all neeessary holes are prepunched. Fourth, with a kit you are assured that the project has been carefully tested and that the finished produet will work. Finally, a eomplete kit will generally cost less than the individual parts bought separately (Figure 4).

On the other hand, "scratch" projects can be challenging and rewarding. They can also be inexpensive if you can scrounge most of the parts from your TV serviceman's junk box. It is a good idea to investigate both kit and "scratch" projects before investing any money.

Schematic Drawings

A schematic (skee-MAT'-ik) diagram is a simple way of showing how electronic components are connected. In this type of diagram, symbols are used to represent electronic components.

A schematic diagram for a code-practice oscillator is shown in Figure 5. A pictorial representation of the same oscillator is in Figure 6. The pictorial shows how the components actually look.

The schematic diagram uses symbols to represent the components. For example, the battery is represented by alternate long and short lines. A resistor (R_1) is represented by a zigzag line. Each type of component is represented by a different type of symbol.

Compare the schematic diagram with the pictorial. Match each symbol in the schematic with its equivalent component in the pictorial. Also, match each line in the schematic with the appropriate wire in the pictorial. Notice the case when two lines cross on the schematic. If the wires represented by these lines are to be connected, a dot is shown at the point of crossing. The absence of a dot means that the two wires bypass each other.

To draw your own schematic diagrams, you will need a sharp pencil, paper, and a ruler or straightedge for drawing straight lines. A compass for drawing circles will also be helpful.

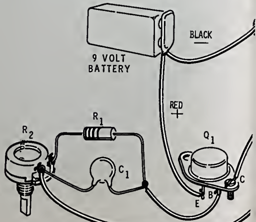


Figure 6

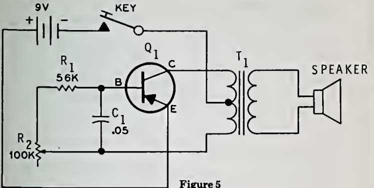
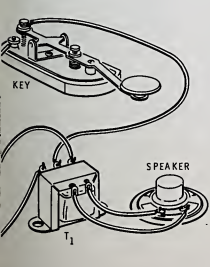


Figure 5



Types of Components

In this section we will describe the most common types of electronic components. The schematic symbol and a pictorial of each component are also given. But first, let's define some of the terms that we will be using.

Electricity is a property that electrons have which causes them to behave in certain predictable ways.

Electrical Charge — a quantity of electricity.

Electron — a tiny particle that has a negative electrical charge.

Current. In this pamphlet, current is defined as the flow of electrons. Current can flow through a wire in much the same way that water flows through a pipe.

Voltage is the pressure that causes current to flow. Voltage can force current to flow through a wire in the same way that water pressure can force water to flow through a pipe.

Resistance is the opposition to current flow. It limits the amount of current flow in much the same way that the diameter of a pipe limits the amount of water flow.

Kilo-(k) is used as a prefix to designate 1,000. For example, the term *kilovolt* means 1,000 volts.

Mega-(m) is used as a prefix to designate one million. Thus, the term megawatt means one million watts.

Micro-(μ) is a prefix that means one-millionth. Thus, a microsecond is one-millionth of a second.

Direct Current (DC) is current that always flows in the same direction.

Alternating Current (AC) is current that reverses its direction of flow many times each second.

Hertz — the basic unit of frequency. One Hertz (abbreviated Hz) is equal to one cycle per second.

Wattage is the amount of power dissipated or required by an electrical component or device.

Resistors. Resistance is defined as an opposition to current flow. A resistor is a device that has a specific amount of resistance. A resistor is somewhat like a faucet in a water line. For a given water pressure, the faucet controls the amount of water that flows. In a similar way, for a given voltage, the resistor controls how much current will flow. Figure 7 shows various types of fixed resistors.

Most resistors are made of a carbon compound. Some that are to be used for higher currents are often made from special wire which is wound on an insulating form. The type of compound or wire used determines how much current can flow for a given voltage.

The value of a resistor is given in ohms. The symbol of ohms is the Greek letter Ω (capital Omega). Thus 1Ω designates a resistance of one ohm. A $1k\Omega$ resistor has a resistance of one kilohm, or 1,000 ohms. A $1M\Omega$ resistor has a resistance of one megohm, or one million ohms.

Fixed resistors like those in Figure 7 cannot be changed. Variable resistors like those in Figure 8 may be changed readily. Variable resistors have a slider that can be moved with a knob or a screwdriver adjustment. Rheostats and potentiometers are types of variable resistors.

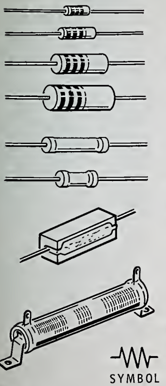


Figure 7

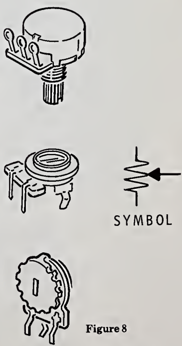


Figure 8

Coils. Many kinds of coils, or inductors, are used in electronics. (See Figure 9.) When a current is flowing through them, energy is stored in the magnetic fields they produce. When a coil is used with a capacitor, a tuned circuit results which has a natural frequency.

This type of circuit is often connected to the antenna of a radio receiver. It tunes one station at a time, ignoring all the stations on frequencies to which it is not tuned. A *choke* is a particular type of coil. It blocks the passage of alternating current, but permits the passage of direct current.

Capacitors. These are storage elements for electric charge, rather like a pot for storing a liquid. Capacitors are shown in Figure 10. The basic unit of capacitance is the *farad*. However, practical capacitors have capacitance values in *microfarads* (μfd). The physical size of a capacitor depends on the voltage rating and the capacitance value. The higher the voltage rating and the larger the capacitance value, the larger the capacitor must be.

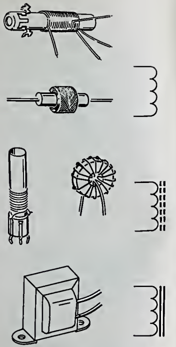
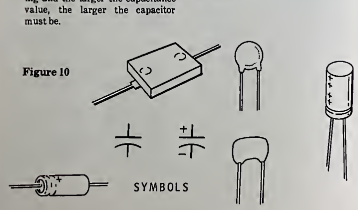


Figure 9

Figure 10



Semiconductor Devices. There are dozens of different types of semiconductor devices. The two most popular are the transistor and the diode.

Transistors, shown in Figure 11, are devices for controlling current. A very small input current controls a much larger output current. For example, the small current from a microphone can control a much larger current which drives a loudspeaker. This is the idea behind the audio amplifiers used in public address systems.

The transistor performs a function similar to that of the electron tube. However, the transistor has smaller size, greater reliability, lower cost, lower power consumption, and longer life. For these reasons, it has replaced the electron tube in most uses.

Second only to the transistor in popularity is the diode. (See Figure 12.) The operation of this device is extremely simple. It passes current in one direction but not in the other. Its most common application is in power supplies. Here it changes alternating current into direct current.

Figure 11

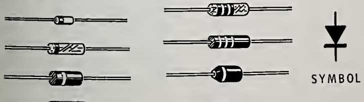


Figure 12

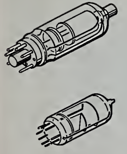


Figure 13

Electron Tubes. The operation of the electron tube (Figure 13) is somewhat similar to that of the transistor. In the tube, a small input voltage is used to control a relatively high output voltage. Thus, the tube can amplify a signal in much the same way as a transistor does.

Today, the transistor has replaced the electron tube in most uses. However, many special-purpose tubes are still used. The most popular is the picture tube in a TV set (Figure 14).

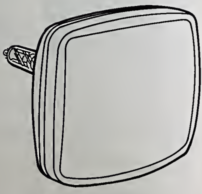


Figure 14

Integrated Circuits (IC's). An IC is a complete circuit within a single package. A typical IC might contain 100 transistors, dozens of diodes, and 20 resistors. All these components are interconnected within a single chip of silicon which may be no more than one-tenth of an inch square.

Complex circuits are available in IC form at very reasonable prices. IC's are reliable, cheap, small, and they consume little power. For these reasons, the IC is replacing traditional components in many applications.

As shown in Figure 15, IC's comc in three different types of packages. The type which looks like a miniature water tower is called a TO5 package. In the flat pack, the leads come straight out of the sides. The dual in-line package (DIP) is the most popular package style for most applications.

TO5

FLAT PACK

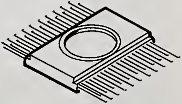
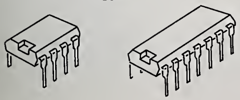


Figure 15

DIPS



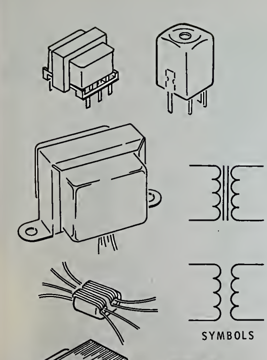


Figure 16

Transformers. The main purpose of the transformer (Figure 16) is to step up or step down voltages or currents. For example, it can change low voltage, high current electricity into high voltage, low current electricity. A transformer is often used as a "go-between" that links two circuits having different characteristics.

Speakers and Microphones. To record or broadcast music and speech, the sounds are first changed into electrical impulses by a microphone. The electrical impulses are then converted back into sound by a speaker. A thin diaphragm in the "mike" vibrates whenever sound strikes it. This causes a current to vary at the same rate as the sound which hits the diaphragm. At the other end, the varying current flows through a magnetic field in the speaker. This causes a diaphragm to vibrate, recreating the original sound. Microphones are shown in Figure 17 and speakers in Figure 18.

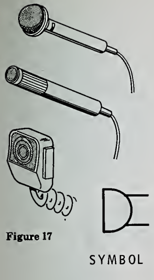


Figure 17

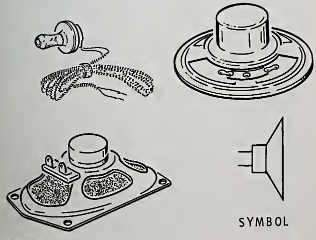


Figure 18

Batteries. Transistor circuits operate at low supply voltage and have low power requirements. Because of this, transistor devices are often driven from small batteries like those in Figure 19. Depending on the type of transistors being used, two to four flashlight cells are often adequate for relatively long service.

Ordinary flashlight dry cells produce approximately 1.5 volts. If 6 volts is called for, this can be provided by four 1.5 volt cells in series. Single 9-volt transistor batteries are also popular.

Batteries are made from several types of materials for different uses. Alkaline and mercury batteries are used where longer life is desired. Nickel-cadmium batteries can be recharged.

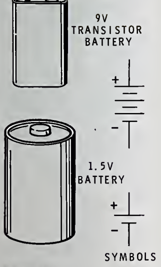


Figure 19

Switches. Switches are an important part of almost all electronic equipment. They come in a wide variety of shapes, sizes, and functions (Figure 20). The simplest is the single-pole, single-throw type. When closed, this switch completes a circuit. When open, it breaks the circuit. The on-off switches on most electronic devices are of this type.

The single-pole, double-throw switch has a contact arm which can be set in either of two positions. In the example shown, terminal A can be connected to either terminal B or terminal C.

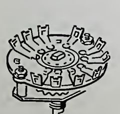
The double-pole, double-throw switch can simultaneously switch two wires from one circuit to another. It can be thought of as two single-pole, double-throw switches which operate together.

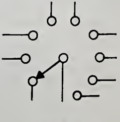
The rotary or selector switch has one or more arms which can be set to a variety of positions. A familiar example of this type of switch is the rotary channel selector used on many TV sets.

SINGLE-POLE, SINGLE THROW

SINGLE-POLE, DOUBLE THROW

DOUBLE-POLE, DOUBLE THROW





SYMBOLS

Figure 20 SELECTOR SWITCH

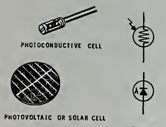


Figure 21

Photoelectric Cells. A photoelectric cell is an electronic component which changes one or more of its characteristics when exposed to light. (See Figure 21.)

One type is called a photoconductive cell. Another name for this type of cell is the light-dependent resistor. This is a special type of resistor which has a small window so that light can strike the resistance material. Generally, such a cell has a very high resistance when in darkness. However, when exposed to light, the resistance drops to a very low value.

Another type is called a photovoltaic cell. This is the familiar "solar cell" used to power electronic equipment on spacecraft. It produces a low voltage across its terminals when it is exposed to light. Thus it converts light energy to electrical energy.

Relays. A relay (Figure 22) can be thought of as a magnetically operated switch. It consists of many turns of wire on an iron core. When current flows through the coil, a magnetic field is developed. The magnetic field attracts an armature. The movement of the armature closes one or more switch contacts. Thus a relatively small current can cause the switch contacts to close. The switch contacts can handle a much heavier current. The relay allows a small current to switch a higher current on or off. Finally, by using several switch contacts, a relay allows a single current to control several different currents simultaneously.

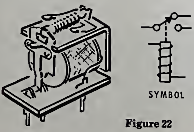


Figure 22

The Color Code of Electronics

You should learn the color code that is used to give the value of resistors.

Resistors are specified in ohms up to a thousand. They are specified in kilohms from a thousand to a million, and in megohms from a million upward.

Most of the resistors you will use are the small carbon-composition fixed type. They are marked with colored bands that tell their values (Figure 23).

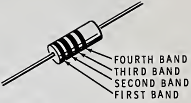


Figure 23

	COLOR	FIRST BAND	SECOND BAND	THIRD BAND*
Better	Black	—	0	
Be	Brown	1	1	0
Right	Red	2	2	00
Or	Orange	3	3	000
Your	Yellow	4	4	0,000
Great	Green	5	5	00,000
Big	Blue	6	6	000,000
Venture	Violet	7	7	0,000,000
Goes	Gray	8	8	00,000,000
West	White	9	9	000,000,000

(Does your memory need a crutch? At the left of each color, you'll see a word beginning with the same letter as the color. These words together form the easily remembered phrase "Better Be Right Or Your Great Big Venture Goes West," to help you remember which color stands for which value.)

*Add this many zeros to your first two numbers.

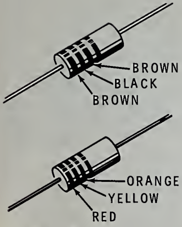


Figure 24

This system was devised by the electronics industry because small printed numbers are hard to read. Also, the numbers might be concealed by the position of the resistor. Memorize the code and then practice it with a few examples that follow.

Notice that the number of zeros indicated by the third band is the same as the number indicated by the color for the other bands.

What about the fourth band on the illustration? If the resistor has a fourth band, it will be either silver or gold. Most of those that you will use in your circuits will have a silver band.

Silver means the resistor may have a value of 10 percent above or below the value shown by the first three bands.

This marking is necessary because it is very difficult to make carbon-composition resistors with an exact value. A gold band means a tolerance of 5 percent. If a resistor has no fourth band, it would have a tolerance of 20 percent, but these are mostly found in older equipment. One percent resistors are also available, but they are very expensive.

Always read the color code by starting with the band nearest the end of the resistor.

Here are a few examples:

Suppose our resistor has a brown first band, a black second band, and a brown third band, as shown at top in Figure 24. The first band is brown. The code chart tells us that the first number is 1. The second band is black. Thus the second number is 0. The third band is brown. This tells us the number of zeros to add. Thus, the value of this resistor must be 100 ohms.

Now let's try a different one at bottom in Figure 24. On it we have a red first band, yellow second band, and orange third band. The red band tells us that the first number is 2. The second band is yellow which corresponds to the number of 4. The third band is orange. This tells us to add three zeros. Thus the value is 24,000 ohms, or 24 kilohms.

Larger resistors, variable resistors, and precision resistors have their values printed on them.

Basic Electronic Theory

Now you are familiar with some electronic terms. In addition, you can identify electronic components by their appearance and by their schematic symbols. Now let's devote some time to the theory behind electronics.

Electronics is the science of controlling electrons. Therefore, our study of electronic theory should begin with the electron.

Atoms and Electrons

All matter is composed of atoms. An atom is made up of a positively charged nucleus around which revolve negatively charged electrons. Generally an atom has one positive charge in the nucleus for each negatively charged electron. Hydrogen has one electron revolving around a nucleus which has one positive charge. Copper has 29 electrons revolving around a nucleus containing 29 positive charges.

There is a basic law of nature that controls electrical charges. Stated simply: *Unlike charges attract; like charges repel.* This means that a negative charge is

drawn to a positive charge, but is pushed away by another negative charge.

Normally the negatively charged electrons are held in place by the attraction of the positive nucleus. However, an electron will sometimes break away from an atom. Once freed, electrons can float around among the atoms. It is these free electrons which are important in electronics. Devices such as resistors, capacitors, and transistors are used to control the behavior of these free electrons.

Conductors and Insulators

Both conductors and insulators are important in electronics. Conductors act as paths for free electrons. They allow electrons to flow where we want them to flow. Insulators act as walls. They prevent electrons from flowing where we do not want them to flow.

The most popular conductor used in electronics is copper wire. Copper has a large number of free electrons floating around among the rigid atoms.

Let's assume that a length of copper wire is connected across the terminals of a battery. The positive terminal of the battery will attract the free electrons in the wire. At the same time, the negative terminal repels the electrons. The result is a flow of electrons through the wire from the negative to the positive terminal. This flow of electrons is called *current.*

An insulator works just the opposite. In some materials all electrons are tightly bound to their atoms. These materials are called insulators. They have very few free electrons. Therefore, if a length of insulator is connected across a battery, no measurable current will flow.

Current, Voltage, and Resistance

Current is simply the orderly movement of electrons. Current flowing through a wire can be compared to water flowing through a pipe.

Current is measured in amperes. One ampere is the movement of about 6 billion billion electrons past a point each second.

Voltage is an electrical pressure that can cause current to flow. It can be compared to water pressure. Voltage forces current to flow through a wire in much the same way that water pressure forces water to flow through a pipe.

The unit of voltage is the volt. A standard flashlight battery produces 1.5 volts. A car battery produces about 12 volts. The light bulbs in your home operate on 115 volts while an electric stove requires about 220 volts.

Resistance is the opposition to current flow. The unit of resistance is the ohm. One ohm is the amount of resistance that will allow one ampere of current to flow when the applied voltage is one volt.

Ohm's Law

Ohm's law describes one of the most basic relationships in electricity. It describes the relationship between voltage, current, and resistance. Stated as a formula:

$$\text{VOLTAGE} = \text{CURRENT} \times \text{RESISTANCE}$$

Using the units of voltage, current, and resistance the formula is:

$$\text{VOLTS} = \text{AMPERES} \times \text{OHMS}$$

We can use this formula to find voltage if current and resistance are known. For example, how much voltage is needed to force 2 amperes of current to flow through 10 ohms of resistance?

$$\text{VOLTS} = \text{AMPERES} \times \text{OHMS}$$

$$\text{VOLTS} = \text{2 AMPERES} \times \text{10 OHMS}$$

$$\text{VOLTS} = 20$$

Thus, 20 volts are required.

The formula can be turned around so that the current can be found if the voltage and resistance are known. The formula is:

$$\text{CURRENT} = \frac{\text{VOLTAGE}}{\text{RESISTANCE}}$$

OR

$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

How much current will flow in a circuit having 5 ohms of resistance when 15 volts are applied?

$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{OHMS}}$$

$$\text{AMPERES} = \frac{\text{15 VOLTS}}{\text{5 OHMS}}$$

$$\text{AMPERES} = 3$$

Therefore, 3 amperes of current will flow.

Finally, the formula can be rewritten so that the resistance can be found if the voltage and current are known. The formula is:

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

OR

$$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

If 12 volts cause 4 amperes of current to flow through a circuit, what is the resistance of the circuit?

$$\text{OHMS} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

$$\text{OHMS} = \frac{\text{12 VOLTS}}{\text{4 AMPERES}}$$

$$\text{OHMS} = 3$$

The resistance is 3 ohms.

Using these formulas you can solve simple problems involving current, voltage, and resistance.

Power

Another important electrical quantity is power. Power is the rate at which work is done. The unit of electrical power is the watt. This can be compared to the unit of mechanical power, the horsepower. One horsepower is equal to 746 watts. The formula for power is:

POWER = CURRENT x VOLTAGE

OR

WATTS = AMPERES x VOLTS

WATTS = AMPERES x VOLTS

This formula allows us to determine the amount of power used by a circuit if the current and voltage are known. For example, how much power is used by a 120-volt toaster which draws 5 amperes?

WATTS = 5 AMPERES x 120 VOLTS

WATTS = 600

Thus, the power used by the toaster is 600 watts. This power is dissipated in the form of heat.

Resistors and Resistance

As already discussed, when a voltage is connected to the ends of a conductor, there is a resulting current. The strength of the current depends on the applied voltage and the resistance of the conductor.

The resistance of a conducting material depends on three factors:

a. Kind of material
b. Length of material
c. Diameter or area of material

The kind of material is perhaps the most important factor. For a specific size conductor, iron has a higher resistance than copper. Carbon has a higher resistance than iron.

Ordinarily, copper is used as the wire material for electric circuits. If we double the length of wire, we double the resistance. Thus, the resistance of a conductor is proportional to the length. The longer the conductor, the higher the resistance will be.

The size of the conductor is important too. A thick conductor will carry more current and offer less resistance than a thin one. Here again, you can compare the flow of electricity in wires with the flow of water through pipes. A big pipe will carry more water for a given pressure than a small one.

When there is a current in a resistor, work is being done to move the electrons. Because of this, heat is produced, and the resistor gets warm.

Heat production by a current is the basis for operation of many electrical devices. Electric heaters, toasters, electric stoves, and soldering irons are some examples. The basic purpose of an electric lamp is the production of light. Nevertheless, most of the electrical energy is converted into heat. The wire filament becomes so hot that it glows. Only a very small fraction of the power goes into light.

In electronic applications, there are two classes of resistors: wire wound and carbon composition.

Carbon resistors are made from a composition that contains graphite or some other form of carbon. This carbon composition is pressed into rod form with wire leads imbedded in each end. This assembly is then covered with a plastic or ceramic material for strength and prevention of moisture damage.

The carbon-composition resistors are cheaper than wire-wound types. Also, they are available in a wide range of resistance values. Standard power sizes are ¼ watt, ½ watt, 1 watt, and 2 watts. These values indicate the maximum recommended power that the resistor can dissipate. The higher the power rating, the larger the resistor.

Wire-wound resistors are made from a metal wire or a metal ribbon wound on an insulating form. Generally, wire-wound resistors are used to handle high current or large amounts of power.

Fixed wire-wound resistors are available in a wide range of resistance values and power capacities. Large-power-capacity resistors are physically large.

Variable wire-wound resistors are provided with a movable arm or slider for easy adjustment to any point on the resistance wire. They may be used as a two-terminal adjustable resistor or rheostat. If both ends of the wire and the slider terminal are available, the unit is called a potentiometer.

Capacitors and Capacitance

A capacitor is a device that can store an electrical charge. Consider two sheets of aluminum or aluminum foil separated by a sheet of waxed paper. Now connect a battery to the two aluminum sheets. After this connection, there will be an initial flow of electrons from the aluminum plate that is connected to the plus terminal of the battery.

Simultaneously, the same number of electrons flow from the negative terminal of the battery to the other aluminum plate.

The number of electrons transferred makes the voltage between the aluminum plates exactly that of the connected battery. If the battery is now removed, the aluminum plates remain in their charged state. If there is no leakage through the waxed paper, the plates will remain charged indefinitely.

Any two conducting plates separated by an insulator make up a capacitor. In the example explained above, the waxed paper served as the insulator.

Of course, the capacitor can consist of many conducting plates with insulating separators. Alternate plates would be connected to form two interleaved stacks. The higher the voltage, the greater will be the amount of charge that is transferred from one plate to the other. The ratio of charge to voltage is defined as the capacitance of the capacitor. The unit of capacitance is the farad. However, this unit is too large for most practical capacitors. Capacitors, therefore, are manufactured to measures of microfarads (millionths) and picofarads (micromicrofarads). The insulating materials used to separate the plates include ceramic materials, mica, certain types of paper, air, and oxide.

One of the most popular types of capacitors is the electrolytic. In this capacitor, the insulator is an extremely thin oxide layer. Because the oxide layer is so thin, large values of capacitance are possible. The leads of electrolytic capacitors are marked positive and negative. This indicates how the capacitor must be connected for proper operation.

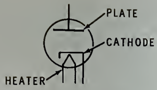
Electron Tubes

The electron tube is largely obsolete today except for special uses. But it was the electron tube that initially made the science of electronics possible.

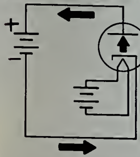
The three most popular types of electron tubes are the diode, the triode, and the pentode.

Diode. A diode allows current to flow in one direction through it but not in the other. It has two main electrodes, which are placed a short distance apart in a vacuum. One is called the plate, the other the cathode. The cathode is heated by a filament (or heater). The cathode is made of a material that emits electrons when heated. Thus, a cloud of electrons surrounds the heated cathode. (See Figure 25.)

If the plate of the diode is con-



ELECTRONS CAN FLOW FROM CATHODE TO PLATE.



ELECTRONS CAN NOT FLOW FROM PLATE TO CATHODE.

Figure 25

nected to the positive side of a battery, the electrons from the cathode will flow to the plate. As we learned earlier, electrons are attracted by a positive charge. Thus, electrons can easily flow from the cathode to the plate.

However, if the negative terminal of the battery is connected to the plate, no current will flow. Let's see why. A negative voltage on the plate will repel the electrons emitted by the cathode. Furthermore, the plate cannot emit electrons of its own because it is not heated. Thus, no current can flow from the plate to the cathode. As you can see, the diode acts like a one-way street. It allows current to flow in one direction but not in the other.

Triode. The triode is a three-element tube. A fine-mesh wire is placed between the plate and the heated cathode. This extra element is called the control grid. The purpose of the grid is to regulate the amount of current that flows through the tube.

When the grid is positive, it attracts the electrons emitted by the cathode. However, since the grid is a mesh wire, most of the electrons pass through the mesh and on to the plate. Thus, if the grid is positive, a heavy current will flow from cathode to plate. (See Figure 26.)

If a negative voltage is applied to the grid, the electrons emitted by the cathode are repelled. Only a few electrons make it through the wire mesh and go on to the plate. If the grid is made negative enough,

no electrons will flow. Thus, the voltage on the grid determines the amount of current that flows through the tube.

As an example, the voltage applied to the grid might come from a microphone. The mike produces a low voltage which corresponds to the sound striking the mike. This low voltage on the grid causes the current through the tube to fluctuate with the sound. The fluctuating current in the speaker reproduces the sound. If the circuit is designed properly, the output sound produced by the speaker will be louder than the original sound. The sound is said to be amplified and the circuit is called an amplifier.

Pentode. The pentode is an improvement over the triode. Two additional electrodes or grids are added between the control grid and the plate. The one closest to the control grid has a positive voltage applied to it. Its purpose is to speed up the electrons that make it through the control grid. A final grid is placed close to the plate. It is sometimes connected to ground. Its purpose is to repel any electrons that "bounce off" the plate.

Today, the electron tube has been largely replaced by the transistor. However, there are special applications in which tubes are still required. They are still used, for example, in high-powered transmitters. Also, several special versions of the tube are still used. The picture tube in your TV set is a special-purpose electron tube.

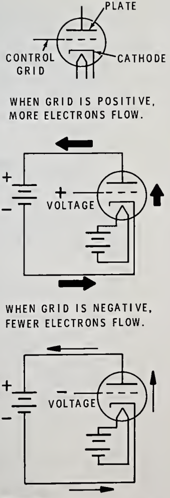


Figure 26

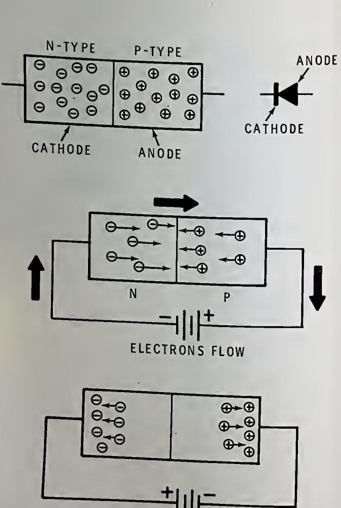

N-TYPE
P-TYPE
ANODE
CATHODE
ANODE
CATHODE
N
P
ELECTRONS FLOW
ELECTRONS CAN NOT FLOW

Figure 27

Semiconductors

"Semiconductors" is a general name given to a wide variety of electronic devices. The most popular semiconductor devices are the diode and the transistor.

Diodes. The semiconductor diode performs the same basic function as the electron-tube diode. It passes current in one direction, but not in the other.

The diode consists of two different types of silicon crystal as shown in Figure 27. An impurity such as phosphorus is added to one area of the silicon. The phosphorus atoms combine with the silicon atoms in such a way that electrons are freed. These electrons float around freely inside the silicon. This type of silicon is called N-type silicon. The N-type silicon is the cathode of the diode.

The other area of silicon has an impurity such as boron added. The boron atoms combine with the silicon atoms in such a way that there is a shortage of one electron in the bonding mechanism. The absence of an electron is called a "hole." This hole can grab an electron from a neighboring atom. However, a new hole is formed when the electron leaves the second atom. Thus, a hole can "float around" from one atom to another in the same way as an electron. The silicon with the "holes" is called P-type silicon. The P-type silicon is the plate or anode of the diode.

Current can flow through the diode in one direction. For current to flow, the negative terminal of the battery must connect to the N-type silicon or cathode, and the positive terminal must be connected to the P-type silicon or anode. The negative terminal of the battery repels the free electrons in the N-type material. The electrons are forced toward the junction where they fill in the waiting holes. However, as the electrons leave the anode, new holes are formed. Thus, there is a constant flow of current from cathode to anode.

Current cannot flow in the opposite direction. If the battery is turned around, the electrons are attracted to the left. Simultaneously, the holes are attracted to the right. Since there are no free electrons at the junction, no current can flow.

Transistors. The transistor was invented in 1947. It is perhaps the most important invention in the history of electronics.

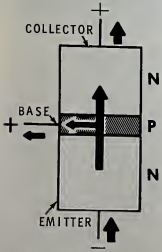
The transistor uses P-type and N-type silicon in much the same way as the diode. However, the transistor has three electrodes. These are identified as the emitter, base, and collector. (See Figure 28.) The collector is connected to the positive terminal of a battery. The emitter is connected to the negative terminal. Thus, electrons will attempt to flow from the emitter to the collector. However, these two elements are separated by a thin layer called the base. If the base is negative, the free electrons in the

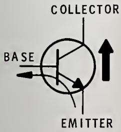
emitter are repelled. In this case, no current can flow from emitter to collector.

However, if the base is positive, electrons can flow into the base from the emitter. Some of the electrons will flow into the positive base lead. But because the base is very thin, most of the electrons travel through the base and into the collector. Making the base more positive causes more electrons to flow. Making the base less positive reduces the current flow. Thus, a small voltage on the base controls the amount of current through the transistor. For this reason, the transistor can be used as an amplifier in much the same way as a vacuum tube.

The transistor shown is called an NPN type. Notice the symbol used to represent the NPN transistor. Another type is called the PNP transistor. Its structure and schematic symbol are shown in Figure 29. It requires opposite polarity voltages for proper operation.

The transistors described above are called bipolar transistors. These are the most popular types used. However, there is a large number of other semiconductor devices which may loosely be called transistors. These include: field effect transistors; unijunction tran-





NPN TRANSISTOR

ELECTRONS FLOW WHEN BASE IS POSITIVE.

Figure 28

sistors, and silicon-controlled rectifiers. These devices will not be discussed in this pamphlet.

Integrated Circuits. As mentioned, an integrated circuit (IC) is a complete circuit in a single package. Transistors, resistors, diodes, and capacitors can be formed in a single chip of silicon. Frequently the entire chip is no larger than 1/10-inch square. Obviously, the individual components must be extremely small. A single chip may contain 1,000 or more electronic components. Manufacturing IC's requires advanced techniques of photography and chemical etching.

There are two basic types of integrated circuits: linear and digital. Linear circuits include amplifiers, oscillators, regulators, and other circuits used in hearing aids, radios, hi-fi amplifiers, and TV sets. Digital circuits include memories, arithmetic circuits, and counters in electronic watches, calculators, and computers.

For those who would like to learn more about basic electronic theory, a list of publications is included at the back of this manual. The *Radio Amateur's Handbook* is also highly recommended.

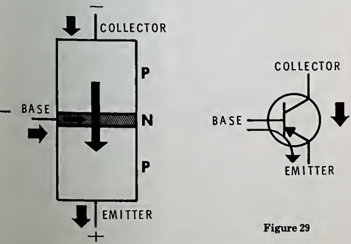


Figure 29

PNP TRANSISTOR

ELECTRONS FLOW WHEN BASE IS NEGATIVE

Soldering

Before doing any work on your circuit, read this chapter on soldering very carefully. One thing an electronics man must know how to do well is soldering.

In all electronics work the wiring connections must be absolutely secure. A loose connection in a radio brings noise, scratching sounds, or no sound at all. In a TV, the sound or picture can be disrupted by poor connections. The operation of airplanes and the lives of astronauts are utterly dependent on secure electronic connections.

Soldering is not just gluing metals together. Done correctly, it *unites* the metals so that electrically they can be considered one piece of metal.

The Solder

The best solder for electronics is called 60-40 rosin-core solder. This means that it is made of 60 percent tin and 40 percent lead. This mixture melts at a lower temperature than either lead or tin. It makes soldering easy and provides good connections.

The rosin keeps the joint clean as it is being soldered. The heat of the iron often causes a tarnish or oxide to form on the surface. The rosin dissolves the tarnish to make the solder cling tightly.

Don't let anyone sell you acid-core solder. It is not for electronic work.

Figure 30

The Iron

An inexpensive pencil-type soldering iron of no more than 40-watt capacity is the best for electronic work. (See Figure 30.) If it has interchangeable tips, this will help.

The gun-type soldering tool is not very good for this kind of work. It often gets too hot, cooking the solder into a brittle mess or damaging small parts of your circuit.

Always exercise caution when soldering. A hot soldering iron can burn your hand badly or ruin a table top. It would be a good idea to buy or improvise a soldering iron holder.

Tinning Your Iron. If your iron is a new one, read the instructions about preparing it for use. If there are no instructions, the following procedure can be used.

Using a fine file, file the tip until it is shiny. Then heat the iron and coat the tip with your rosin-core solder.

If you have an older iron and the point is already silver-looking, just wipe it clean with a cloth and you are ready for work. If it is dull or looks coppery, file and tin it as you would a new iron.

NOTE: Some new irons are already tinned. If the tips are silvery, do not disturb them, but use them

as they are. If you do tin your iron, do it on all sides of the tip.

How To Solder

A well-soldered joint depends on:

1. Soldering with a clean, well-tinned tip.
2. Cleaning the wires or parts to be soldered.
3. Making a good mechanical joint before soldering.
4. Allowing the joint to get hot enough before applying solder.
5. Allowing solder to set before handling or moving the soldered parts.

Preparing Work for Soldering. When old junk parts are used, all wires or surfaces must be completely clean before applying solder. Remove all enamel, dirt, scale, or oxidation by sanding or scraping them down to the bare metal. Use fine sandpaper or emery paper to clean flat surfaces or wire. Incidentally, no amount of cleaning will allow you to solder to aluminum. When making a connection to a sheet of aluminum, the wire must be connected by a solder lug or a screw.

When preparing wires, remove the insulation with wire strippers or a pocketknife. If you use a knife, do not cut straight into the insulation. You might nick the wire and weaken it. Instead, remove the insulation by holding the knife as if you were sharpening a pencil, taking care not to nick the wire.

If the wire is enameled, use the back of the knife blade to scrape the wire until it is clean and bright. Then *tin* the clean end of the wire. This is done by holding the heated soldering-iron tip against the under surface of the wire and placing the end of the rosin-core solder against the upper surface. As the solder melts, it flows on the clean end of the wire.

Hold the hot tip of the soldering iron against the *under* surface of the tinned wire and remove the excess solder by letting it flow down on the tip. When properly tinned, the exposed surface of the wire should be covered with a thin, even coating of solder.

Making a Good Mechanical Joint. Unless you are making a temporary joint, the next step is to make a good mechanical connection between the parts to be soldered. For instance, wrap wire carefully and tightly around a soldering terminal or soldering lug. (See Figure 31.) Bend wire and make connections with long-nosed pliers.

When connecting two wires, make a tight splice before soldering. Once a good mechanical contact is made, you are ready for the actual soldering.

Figure 31.

Attach the wire.

Figure 32

Heat both the wire and the lug.

Figure 33

Apply solder to both the tip and the connection.

Figure 34

Let the connection harden before moving the wire. Then, check for a smooth bright joint.

Poor connections look crystalline and grainy or the solder tends to blob.

Figure 35

Soldering a Joint. The next step is to apply the soldering iron to the joint. (See Figure 32.) In soldering a wire splice, hold the iron below the splice and apply rosin-core solder to the top of the splice. If the tip of the iron has a bit of melted solder on the side held against the splice, heat is transferred more readily to the splice, and the soldering is done more easily. (Figure 33). Be sure not to disturb the soldered joint until the solder has set.

It may take a couple of seconds or so for the solder to set, depending upon the amount of solder used in making the joint (Figure 34). Don't try to solder by applying solder to the joint and then pressing down on it with the iron.

Now take a good look at the joint. It should have a shiny, smooth appearance — not pitted or grainy. If it does have a pitted, granular appearance (Figure 35), reheat the joint, scrape the solder off, and clean the connection — then start all over again. Pull on the wire to see if it is good and tight. Don't get angry if you find a poor soldering job — be thankful you discovered it!

How To Unsolder

It is also important to know how to unsolder connections. You may accidentally make a wrong one or have to move a component (part) that you have put in a poor location.

Unless great care is taken while unsoldering, good parts may be broken or destroyed. The leads on

parts such as resistors or transistors and the lugs on other parts may sometimes break off when a good tight joint is being unsoldered.

Just as much care has to be used in unsoldering delicate parts as in soldering them, if heat damage is to be avoided.

There are two easy ways of unsoldering. The first way involves the use of a metal wick or braid to remove the melted solder. (See Figure 36.) This braid is available at most electronic parts stores. The braid is placed against the joint that is to be unsoldered. The heated soldering iron is used to gently press the braid against the joint. As the solder melts, it is pulled into the braid. By repeating this process, virtually all the solder can be removed from the joint. The joint can then be reheated and the leads lifted off.

The second method is just as easy. It uses a vacuum device to suck up the molten solder. These devices are also available at most electronic parts stores.

A desolder squeeze bulb was shown earlier. When using this device, the joint that is to be unsoldered is heated with your soldering iron until the solder melts. The bulb is then squeezed to create a vacuum inside. The tip of the bulb is touched against the molten solder. When the bulb is released, the molten solder is pulled into the bulb. The process should be repeated until most of the solder is removed from the joint. The wires can then be gently pried off after reheating the joint.

Here are some things to remember when unsoldering.

1. Be sure that there is a little melted solder on the tip of your iron so that the joint may be heated quickly.
2. Work quickly and carefully to avoid heat damage to parts. Use long-nosed pliers to hold the leads of components just as you did in soldering.
3. When loosening a wire lead, be careful not to bend the lug or tie point to which it is attached.

Now that you have read how to solder, experiment a little before you actually start soldering on your circuit. Take some pieces of wire or some old radio parts and wire. Practice until you are smooth, shiny, and tight. Then practice unsoldering connections until you are satisfied you can do them quickly and without breaking wires or lugs.

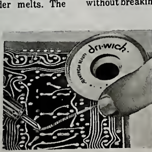


Figure 36

Soldering Printed Circuit Boards

Most electronic devices use one or more printed circuit (PC) boards. A PC board is a thin sheet of fiber glass or phenolic which has a pattern of foil conductors "printed" on it. Component leads are inserted into holes in the board and are soldered to the foil pattern. This method of assembly is widely used and you will probably encounter it if you choose to build a kit.

Printed circuit boards make assembly easy. First, a component is inserted through the correct holes in the circuit board. Parts should be mounted tightly against the circuit board unless otherwise directed. Once inserted into the board, the lead should be bent slightly outward to hold the part in place.

Touch the tip of the soldering iron to both the component lead and the foil until they are hot enough to melt solder (Figure 37). Next apply a small amount of solder to both the tip and the connection (Figure 38). Remove the iron and let the solder harden before moving the wire or the board (Figure 39). The finished connection should be smooth and bright. Reheat any cloudy or grainy-looking connections. Finally, clip off the excess wire length (Figure 40).

Occasionally a solder "bridge" will form between two adjacent foil conductors (Figure 41). Such bridges must be removed; otherwise a *short circuit* will exist between the two conductors. Solder bridges can be removed by heating the bridge and quickly wiping away the melted solder with a soft cloth.

Often you will find one of the holes on the board plugged by solder from a previous connection. The hole can be cleared by heating the solder while pushing a component lead through the hole from the other side of the board (Figure 42).

Care of Your Soldering Iron

To get the best service from your soldering iron, keep it cleaned and well tinned. Keep a damp cloth on the bench as you work. Before soldering a connection, wipe the tip of the iron across the cloth, then touch some fresh solder to the tip.

Eventually the tip will become worn or pitted. Minor wear can be repaired by filing the tip back into shape. The tip must be tinned immediately after it is filed. If the tip is badly worn or pitted, it should be replaced. Replacement tips may be bought from most electronic parts stores.

Remember that oxidation is much more rapid when the iron is hot. Therefore you should not keep it heated for long periods of time unless you are using it. Do not try to cool it rapidly with ice or water. If you do, the heating element may be damaged and need to be replaced or water may get into the barrel and cause rust. Take care of your soldering iron and it will give you many years of useful service.

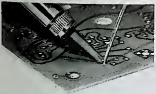


Figure 37

Figure 38

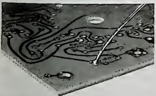


Figure 39

Figure 40

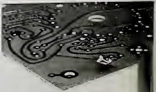


Figure 41

Figure 42

Control Devices

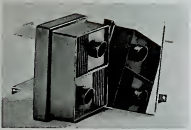


Figure43

To satisfy requirement 3, you will get into the real adventure of electronics. You will build a working electronic circuit. You may select a control project, an audio project, or a digital project. Several projects of each type are recommended in this pamphlet.

You may select any one of these kits or "scratch" projects. Or you may select an alternate project of your own choosing. However, you should check with your counselor to be certain that the project you select is suitable.

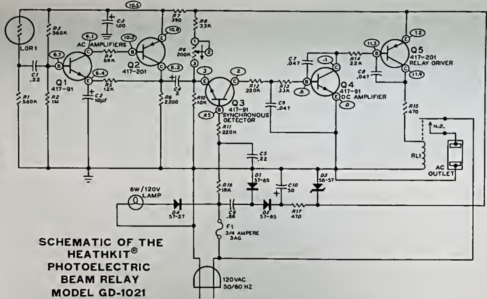
An important application of electronics is the control of certain operations. For example, lights can be made to go on at dusk. Doors can be opened automatically. Burglar alarms can be made to go off when a light beam is broken.

Kit Project

The first control project that we will consider is an electronic kit. It is called a photobeam relay. The unit shown in Figure 43 is the Heathkit® model GD-1021. The kit contains a light source, a mirror assembly, and a photocell controlled relay. The relay is activated whenever the reflected light beam is broken. This, in turn, energizes the AC socket on the unit. Any warning device or lamp plugged into this socket is then activated. When the light beam is no longer obstructed, the photo relay shuts off power to the alarm or lamp.

This device can be used for many purposes. It can act as a burglar alarm. Or it can signal when someone goes in or out of your room. If a counter is attached, it can be used to count the number of people or objects passing a given point.

Circuit Operation. A schematic diagram of the photobeam relay is shown in Figure 44. When the unit is plugged in, the lamp glows. A lens focuses the light into a narrow



SCHEMATIC OF THE HEATHKIT® PHOTOELECTRIC BEAM RELAY MODEL GD-1021

Figure 44

NOTES:

1. ALL RESISTORS ARE 1/2 WATT (10%) UNLESS MARKED OTHERWISE. RESISTOR VALUES ARE IN OHMS (K= 1000, M= 1,000,000).
2. ALL CAPACITORS ARE IN µF.
3. THIS SYMBOL DENOTES THE CLOCKWISE ROTATION OF A CONTROL WHEN VIEWED FROM THE SHAFT END OF THE CON
4. THIS SYMBOL INDICATES A DC VOLTAGE, MEASURED FROM THE POINT INDICATED TO GROUND.
5. VOLTAGE MEASUREMENTS ARE TAKEN WHEN THE UNIT IS PLUGGED INTO AN AC VOLTAGE SOURCE, WITH NO EXTERNAL DEVICE BEING ACTIVATED.

ALL VOLTAGES ARE MEASURED WITH A HIGH IMPEDANCE VOLTMETER.

beam. The beam of light shines into a mirror, which can be located some distance away. The mirror reflects the light beam back to the unit. The reflected beam strikes the light-dependent resistor (LDR 1).

The light beam varies in intensity 60 times each second. Thus, the LDR changes its resistance value at the same rate. This produces a 60 Hz signal which is amplified by Q_1 and Q_2.

From Q_2, the signal is applied to Q_3. This transistor stage is called a synchronous detector. The purpose of this circuit is to separate the desired 60 Hz signal from unwanted signals. Obviously, the unit should respond only to its own light source and not to sources such as overhead lights, flashlights, reflected sunlight, etc. Q_3 compares the received signal with the 60 Hz signal which originally lit the lamp.

The two signals applied to the synchronous detector agree only if the light beam is not broken. In this case, Q_3 produces an output voltage which holds Q_4 cutoff. In turn, Q_4 holds Q_5 cutoff. Consequently, no current can flow through the relay (RL1). Thus the relay contacts are left open and no AC voltage is present at the AC outlet.

When the light beam is broken, the two signals applied to the synchronous detector do not agree. Q_3 produces an output voltage which causes Q_4 to conduct. In turn, Q_4 causes Q_5 to conduct. The current through Q_5 also flows through the relay. The relay closes its contacts, applying the AC line voltage to the AC outlet. Thus an alarm or lamp plugged into the AC outlet will be activated when the light beam is broken.

Precautions. Because this unit is powered by the AC line voltage, certain precautions must be taken. The assembly instructions that come with the kit must be followed. You should never plug in the unit until it is completely assembled.

You should not attempt to build this project from scratch, but only from the kit. This applies to any project powered by the 120-volt AC line. If you prefer "scratch" projects, you should choose one that is battery-powered. Several battery-powered projects are included in this pamphlet.

Alternate Kit Projects

There are several other control kits available from the kit companies listed at the back of this pamphlet.

A very inexpensive kit is the photoelectric lamp switch. It turns lights on at night, off in the morning — automatically. The unit shown in Figure 45 is the Heathkit model GD-600. You just plug it into any wall socket and plug the lamp you wish to control into the back of the unit. At dusk, the lamp is automatically turned on. At dawn, the lamp is turned off.

Another possibility is a lamp

Figure 45

Figure 46

dimmer. The Heathkit model GD-1018 is shown in Figure 46. With this device, you can set just the right amount of light for reading, watching TV, etc. It conserves energy and extends bulb life. It can also double as a heat-control device for your soldering iron.

"Scratch" Control Project

You may prefer to build a project from scratch to satisfy this requirement. The one shown in Figure 47A is easy to build and fun to use. It is a low-power flasher circuit. The circuit sits on top of a 6-volt lantern battery and flashes brightly about once a second. It makes a dandy warning light or a sure-fire attention getter. Because of its low power, it will flash for many hours before running down the battery.

Building the Circuit. If necessary, carefully trim the perforated board so that it is the same shape and size as the top of the battery. This can be done with a coping saw if you take your time. Next, drill two

Figure 47A

holes in the board so that the battery posts can stick through. Now mount your components on the board as shown in Figure 47A. Notice that the components are mounted on top of the board while the interconnections are made underneath. Follow the schematic diagram in Figure 47B closely as you make each connection.

When you have finished the circuit, connect the - and + terminals shown on the schematic to the proper terminals on the battery. Be sure the - terminal on the circuit board is connected to the - terminal on the battery. When both terminals are connected, the lamp should blink on and off about once each second. If it does not, recheck all your wiring and your solder connections.

Parts List

To construct this project, you will need the following parts:

R_1	3.0 megohm	10%	½ watt carbon resistor
R_2	12 megohm	10%	½ watt carbon resistor
R_3	18 megohm	10%	½ watt carbon resistor
R_4	4.3 megohm	10%	½ watt carbon resistor
R_5	270 kilohm	10%	½ watt carbon resistor
C_1	0.47 ufd	capacitor	
IC_1	CA3094	linear integrated circuit	
1	lamp #1850 or equivalent		
20	terminal posts (optional)		
1	lamp socket		
1	6-volt lantern battery with screw-on terminals NEDA #915		
1	piece of perforated board about 2.5 in. square		

How It Works. The heart of the circuit is the CA3094 linear integrated circuit. This device is called a programmable switch. It provides a current to light the lamp when the voltage at pin 3 is higher than the voltage at pin 2.

The voltage at pin 2 is set to 4.8 volts by R_1 and R_2. The voltage at pin 3 is controlled by the charge and discharge of capacitor C_1. When power is applied to the circuit, the voltage at pin 3 increases slowly as C_1 charges. It takes this voltage about one second to surpass the 4.8 volts at pin 2. As soon as the voltage at pin 3 goes higher, the IC produces a current at pin 8. This current flows through the lamp, causing it to blink. However, C_1 immediately discharges and the voltage at pin 3 drops below that at pin 2. Thus, the IC cuts off current to the lamp. This cycle is repeated over and over again, causing the lamp to blink on and off once per second.

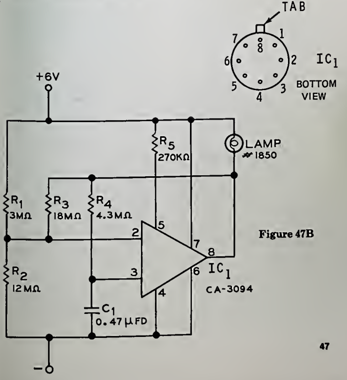


Figure 47B

Digital Electronics

In the past decade, there has been a revolution in the electronics industry. Digital electronics have begun replacing traditional circuits and components. A whole family of new electronic devices has been developed. The calculator is a good example of this trend. Other examples are digital clocks and wrist watches that print out the time as numbers.

To understand digital electronics, we must first learn the number system used in digital equipment. It is called the binary number system. It is different from our familiar decimal system.

Binary Number System

The number system we have always used is called the *decimal* system. It uses 10 different digits (0, 1, 2, 3, 4, 5, 6, 7, 8, and 9). This number system is suitable for humans, but it is too complex to be used by electronic circuits. To keep circuits simple, a simple number system called *binary* is used. The binary number system has only two digits, 0 and 1. These digits mean exactly the same things they mean in the decimal system. Since it uses only two digits, you may wonder how we can represent numbers greater than 1. The answer is "the same way we represent numbers greater than 9 in the decimal system."

In the decimal system, the highest single-digit number is 9. We represent numbers higher than this by using two or more digits in combination. That is, ten is represented by using the digits 1 and 0 together to form 10.

In the binary system, the highest single digit number is 1. To represent numbers higher than this, we use two or more digits in combination. The number two cannot be represented by the symbol"2." This symbol is not used in the binary system. Instead we must use the digits 1 and 0 together to form 10. Thus, in the binary system 10 represents the number two and not the number ten. The number three is represented by the next larger two-digit number, or 11.

Now, how do we represent the number four in binary? Since we have run out of two-digit possibilities, we must use a three-digit number. The lowest three-digit number is 100. In the decimal system, this meant one hundred. But, in the binary system this means four.

Let's compare more decimal and binary numbers:

Decimal	Binary	Decimal	Binary
0	0	9	1001
1	1	10	1010
2	10	11	1011
3	11	12	1100
4	100	13	1101
5	101	14	1110
6	110	15	1111
7	111	16	10000
8	1000	17	10001

Study this listing until you understand the binary sequency. Can you continue the list to thirty-two (decimal) or 100000 (binary)?

Changing From Decimal to Binary. If you can divide by 2, you can convert decimal numbers to binary numbers. When we divide an even number by 2, the remainder is always 0. When we divide an odd number by 2, the remainder is always 1. By repeatedly dividing by 2 and recording the remainders, we can convert from decimal to binary.

For example, let's convert the decimal number 8 to binary:

8 divided by 2 = 4 with a remainder of 0
4 divided by 2 = 2 with a remainder of 0
2 divided by 2 = 1 with a remainder of 0
1 divided by 2 = 0 with a remainder of 1

Finally, we arrange the remainders like this: 1 0 0 0
This gives us the binary number for 8. Check the list given earlier. Verify that 1000 in the binary system represents 8.

To be sure you have the idea, let's convert 13 to a binary number:

13 divided by 2 = 6 with a remainder of 1
6 divided by 2 = 3 with a remainder of 0
3 divided by 2 = 1 with a remainder of 1
1 divided by 2 = 0 with a remainder of 1

The remainders are then arranged like this: 1 1 0 1.
Our earlier lists shows that 1101 is the binary equivalent of 13.

Changing From Binary to Decimal. Changing numbers in the opposite direction is also easy. The procedure can best be illustrated by an example. Let's convert the binary number 1011 to its decimal equivalent.

First, we write the binary number with the digits spread well apart like this:

1 0 1 1

Under the digit on the right, we write the number 1. Under the next digit we write the number 2. Under the next we write the number 4. Under the next, we write the number 8, and so forth. Thus, our work looks like this:

1 0 1 1
8 4 2 1

The lower row of numbers is formed by starting with 1 on the right and progressively doubling as we move to the left.

Finally, we add together the lower numbers which are written under a 1. Notice that 8, 2, and 1 are written under 1's. However, 4 is written under a 0. Thus, we add 8 + 2 + 1 = 11. Consequently, 1011 is the binary representation of the decimal number eleven.

Let's try another example. Convert the binary number 10110 to a decimal number.

1 0 1 1 0
16 8 4 2 1
16 +4 +2 = 22

Try converting some binary numbers of your own to decimal. Check your answers against the list given earlier.

Logic Circuits

Digital electronic devices are made up of circuits called logic gates. A logic gate is simply a collection of transistors and resistors connected so that they perform a desired operation. There are three basic types of logic gates. They are the AND gate, the OR gate, and the INVERTER.

The AND Gate. The simplest AND gate has two inputs and one output. (See Figure 48.) This circuit examines the input voltage levels and produces an appropriate output voltage level. Recall that digital systems use the binary number system. Therefore, only two voltage levels are used. One voltage level stands for the number 0. The other stands for the number 1. A common arrangement is to let 0 volts stand for the number 0 and to let +5 volts stand for the number 1.

An AND gate produces a "1" output only when all inputs are "1's." That is, for the arrangement discussed above, the output of the AND gate is +5 volts (1) only when all inputs are +5 volts (1). If either input is 0 volts (0), the output will be at 0 volts (0). This gate gets its name from the fact that the output is 1 only if input 1 AND input 2 are 1's.

Some AND gates have more than two inputs. However, the operation performed is the same. The output is 1 only when all inputs are 1's. If any input is 0, then the output will also be 0. For this reason, the AND gate can be thought of as an "all or

nothing" decision circuit. It examines all the inputs and produces a 1 output only when all inputs are 1's.

The logic symbol for the AND gate is shown. Notice that it resembles the letter D. The inputs are shown on the flat side. The output is shown on the curved side. This symbol is used on schematic diagrams.

The OR Gate. The OR gate is also a decision making circuit. (See Figure 49.) It produces a 1 output when any one or all of its inputs are 1. Thus, it produces a 1 output when input 1 OR input 2 OR both are 1's. The only time the OR gate produces a 0 output is when all inputs are 0's. It can be thought of as an "any or all" decision circuit. If any one or all of its inputs are 1, the output will be 1.

The Inverter. The inverter (Figure 50) performs the simplest operation of all. It has only one input and one output. If the input is 0, the output is 1. If the input is 1, the output is 0. That is, the inverter reverses or inverts the input.

Other Gates. There are two other types of logic gates used in digital electronics. One is called the NAND gate (Figure 51). This circuit is composed of an AND gate and an inverter connected together. The output of the AND gate is applied to the input of the inverter as shown. Generally, the logic symbol is simplified as shown.

In a similar manner, an OR gate and an inverter can be connected to form a NOR circuit (Figure 52).

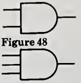


Figure 48

AND GATES

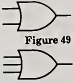


Figure 49

OR GATES

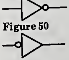


Figure 50

INVERTERS

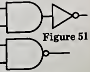


Figure 51

NAND GATE

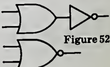


Figure 52

NOR GATE

The output of the OR circuit is inverted as shown.

Logic gates are generally made in integrated circuit (IC) form. A single IC package may contain four NAND gates or six inverters.

Digital Equipment

These basic gates can be connected in various ways to perform many different operations. Circuits have been devised that can count, add, subtract, remember numbers, and make complex decisions. In turn, these circuits can be connected to form an array of useful electronic equipment. Let's look at some of the more popular digital devices.

Electronic Computers. The electronic computer can solve mathematical problems very rapidly. In addition, it can store and process data that is not mathematical in character. See Figure 53.

Computers can control spacecraft in flight. They are also used in industry for calculating payrolls, for keeping records, and for inventory control.

Also, many nonmathematical uses have been found for computers. These include ticket control by the airlines and library recordkeeping. They can even translate one language into another.

To use a computer, we must communicate with it. This is done in one of two ways. In one method, a program or set of instructions to the computer is written and punched on special cards. The cards are inserted into a card reader that transfers the information into the memory. Later this program will be called. The machine follows the instructions.

The computer stores the results. The program plus the results will then be available for printout.

A second way of communicating with a computer is through a terminal. The terminal resembles a typewriter. Information is entered directly into the machine via the keyboard. This process is relatively slow. For this reason, a computer will usually accommodate a number of terminals at the same time. The computer must use different places in the memory for each program or the different programs will interfere with each other.

Electronic Calculators. The calculator (Figure 54) uses the same type of arithmetic circuits found in the computer. However, the method of entering data and reading out the answer is greatly simplified. Also, the operations that the calculator can perform are generally limited to a few mathematical functions. Nevertheless, because of its low cost and ease of operation, the calculator has become a valuable aid. It is particularly important to those who must perform a great deal of routine mathematics.

Electronic Clocks and Watches. Digital clocks (Figure 55) and watches are rapidly replacing their mechanical counterparts. In these devices an extremely accurate oscillator produces thousands of pulses each second. Electronic circuits count these pulses and convert them to a display of the time in hours, minutes, and seconds.

Test Equipment. Digital techniques offer several advantages in electronic test equipment (Figure 56). Digital voltmeters are generally more accurate and easier to read than the meter-movement type of instrument. Another popular test instrument is the frequency counter (Figure 57).

Other Devices. Several other types of digital equipment are becoming increasingly popular. These include the digital thermometer, scale, and cash register. Digital techniques are used in electronic musical instruments, TV receivers, transmitters, and appliances.

Figure 53

Figure 54

Figure 55

Figure 56

Figure 57

Digital Counter

We can build a circuit that will demonstrate digital techniques. The details for such a circuit are given below.

The circuit is a counter which has both a binary and a decimal display (Figure 58). The circuit counts the number of times that the pushbutton switch is depressed. The four light-emitting diodes on the right display the count as a binary number. The 7-segment display on the left gives the count as a decimal number. The highest count the circuit can display is 9.

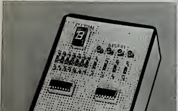


Figure 58

Circuit Operation. As the schematic diagram in Figure 59 shows, most of the circuit is composed of three integrated circuits. The 7490 IC is a BCD counter. BCD stands for "binary coded decimal." BCD is a compromise between the binary system and the decimal system. The counter sequences from 0 to 9. Notice that each decimal digit is represented by a count. However, the count itself is in binary. Thus, the counter follows this sequence:

0000	0100	1000
0001	0101	1001
0010	0110	0000
0011	0111	0001
		etc.

Notice that the circuit counts from zero to nine. It then recycles to zero and begins counting again. The count advances once each time the pushbutton (S_2) is depressed.

The counter has four output lines. These are labeled A, B, C, and D on the schematic. Each line carries one of the digits of the binary number.

The binary number is applied to the BCD-to-7 segment decoder/driver. This circuit is a 7447 integrated circuit. It accepts the binary number and converts it to a form suitable for driving the 7-segment display.

This display consists of 7 light-emiting diodes labeled a through g.

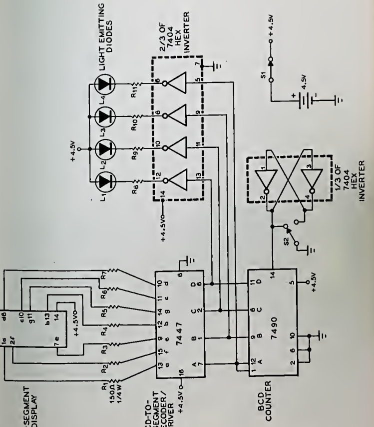

7-SEGMENT DISPLAY
BCD-TO-7-SEGMENT DECODER/DRIVER
7447
BCD COUNTER
7490
LIGHT EMITTING DIODES
2/3 OF 7404 HEX INVERTER
1/3 OF 7404 HEX INVERTER
+4.5V
4.5V
S1
S2
150Ω 1/4W

Figure 59

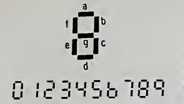


Figure 60

The diodes are arranged as shown in Figure 60.

By lighting the proper segments any digit from 0 to 9 can be formed. If segments a, b, and c are lit, the digit 7 is formed. When all segments are lit, the digit 8 is formed. The purpose of the 7447 is to decode the binary count and drive the proper segments of the display.

A binary display is also provided. Four light-emitting diodes are driven by four of the inverters on the 7404 IC. The inputs to these inverters also come from the 7490 IC. The four inverters provide the current necessary to drive the light-emitting diodes.

Two inverters in the 7404 are used in connection with the push-button (S2). Some switches have a momentary bounce when they are operated. That is, they actually open and close several times due to vibrations within the switch. While this happens too fast for us to see, the counter will respond to the bounces. In this case, the counter will appear to be counting incorrectly. The purpose of the two inverters is to eliminate the effects of contact bounce.

The types of integrated circuits used in this project normally operate with a supply voltage of 5 volts. However, they will operate satisfactorily from 4.5 volts. This is achieved by connecting three D cells in series. S1 serves as the on-off switch. Resistors R_1 through R_{11} are used to hold the current for the displays down to an acceptable level.

Building the Circuit. This circuit (Figure 61) is somewhat more difficult to build than most of the others in this pamphlet. It will tax your soldering ability and your patience. The pins on the integrated circuits are only one-tenth of an inch apart. It is extremely easy to bridge two of these pins with solder. When this happens, remove the bridge, using one of the desoldering techniques discussed earlier in this pamphlet.

The circuit should be constructed on perforated board. Furthermore, the board must have a hole pattern suitable for IC's. That is, the holes must be 1/10-inch (0.1 inch) apart. Boards of this type are quite common. All components except the battery will mount on this board.

The integrated circuits and the 7-segment display can plug directly into the board; or IC sockets can be used. The resistors can be soldered to terminal posts as shown. Or the leads can be bent and inserted directly through the board. All interconnections are made on the bottom of the board. Wires are soldered directly to the leads of the IC's or the IC sockets. In some cases two wires must be soldered to a single pin.

It is recommended that you use very small insulated wire for this

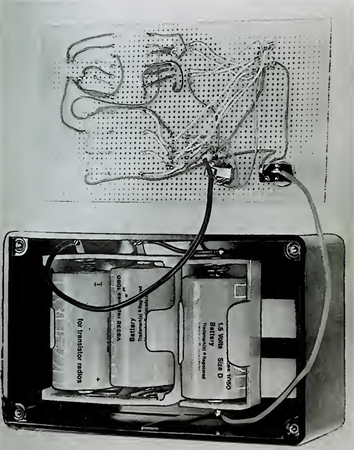


Figure 61

purpose. Number 26 wire is a good choice. Also, a soldering iron with a very small tip is required.

The three D cells are mounted in the plastic box. Double-sided tape can be used to hold the battery holders in place. Make certain that the box you buy is big enough to hold the batteries. The perforated board serves as the top of the box. The board should be the same size as the box; or it should be large enough so that it can be cut down to fit the box.

Extreme care should be taken when cutting the board. Most boards are brittle and break easily. Buy switches that will mount in small round holes. Be careful when drilling these holes.

The light-emitting diodes (L1 through L4) must be connected properly before they will light. The anode leads must be connected together and to the positive side of the battery.

The package in which the diodes come should show you how to identify the anode lead. If it does not, follow this procedure. Connect your three D cells together as shown in Figure 62. Temporarily solder a 150-ohm resistor to the negative terminal of the first battery holder. Temporarily solder an insulated wire to the positive terminal of the last battery holder. Touch one lead of the LED to the free end of the resistor. Touch the other lead of the LED to the free end of the wire. If the LED lights, the anode is the lead connected to the wire. If it does not light, the anode lead is connected to the resistor. Turn the LED around and verify that it lights when the anode lead touches the wire.

It is equally important that you be able to identify the pins on the integrated circuits. Here again the package they come in may show you how. If not, the pins can be identified in one of the ways shown in Figure 63.

Notice that there is always some orientation mark. This mark may be a notch, an indentation, or simply a spot of paint. When this mark is on the left as shown, pin 1 will be the lower left pin. The other pins are always numbered in the sequence shown.

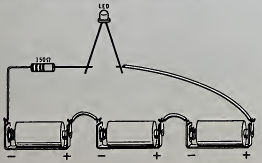


Figure 62

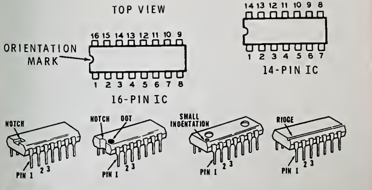


Figure 63

The pins on the 7-segment display are identified in much the same way. Some type of orientation mark is used to identify pin 1. Then the pins are numbered in the same way as the 14-pin IC's. However, there may be one important difference. On most 7-segment displays, not all 14 pins are present. Some use as few as 10 pins. When numbering the pins, we must count the space where the pin normally would be. In the example shown in Figure 64, pins 4 and 5 are missing. Nevertheless, the spaces are counted as pins.

It is important to remember that the top view of the pin arrangements is shown. When soldering to these IC's, you will be viewing them from the bottom. This can easily cause confusion. To simplify things, it is a good idea to mount all IC's first. Insert the leads of the IC or the IC socket through the holes in the board. Temporarily tape the IC's or sockets in place to prevent them from falling off when the board is turned upside down. Then turn the board over and label each pin number. You can write directly

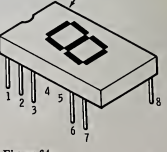


Figure 64

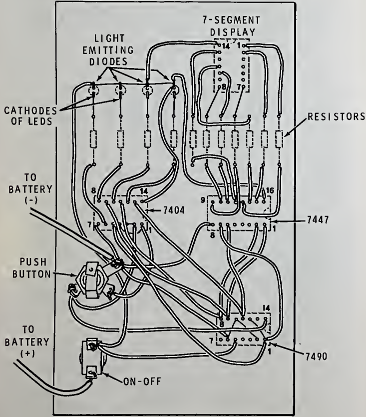

7-SEGMENT
DISPLAY
LIGHT
EMITTING
DIODES
14
1
8
7
CATHODES
OF LEDS
RESISTORS
TO
BATTERY
(-)
8
14
9
16
7404
7
1
8
1
7447
PUSH
BUTTON
14
8
TO
BATTERY
(+)
7
1
7490
ON-OFF

Figure 65

on the board with a pencil or pen. Figure 65 shows all the wired connections as viewed from the bottom side of the board.

Refer to the pictorial and the schematic diagram as you solder each connection. Take your time and work carefully. Make certain there are no solder bridges between adjacent pins. When you have completed construction, recheck everything before applying power. Finally, insert the batteries in their holders and turn the device on.

When the power switch is turned on, some segments of the 7-segment display should be lit. These segments may or may not form a recognizable digit. Depress the pushbutton several times until the digit "0" is displayed. The count should now advance once each time the pushbutton is depressed and released. Upon reaching a count of 9, the device should recycle to 0. Notice the four LED's also. These devices should be counting in binary. A 1 is represented when the LED is on. A 0 is represented when the LED is off. The binary count should always agree with the decimal count.

Parts List
- 1 plastic box (3½" x 2" x 6" recommended)
- 1 perforated board (1/10-inch hole pattern)
- 1 SN7490 BCD counter, IC
- 1 SN7447 BCD-to-7 segment decoder/driver, IC
- 1 single-pole single-throw switch (S_1).
- 1 single-pole double-throw pushbutton switch (S_2)
- 3 battery holders
- 3 D cells
- 4 light-emitting diodes (20 milliampere)
- 1 SN7404 Hex inverter, IC
- 1 7-segment display (Monsanto type MAN-1, MAN-5, MAN-7, or MAN-8; Texas Instrument type TIL 312, TIL 314, or TIL 316; Opcoa type SLA-1, SLA-7, SLA-11, or SLA-21; or Calectro type J4-900.)
- 11 150-ohm ¼-watt or ½-watt carbon resistors (R_1 through R_{11})
- 3 14-pin dual-in-line IC sockets (optional)
- 1 16-pin dual-in-line IC socket (optional)
- 22 terminal posts (optional)
- 6 feet of very small insulated wire (No. 26 recommended)

Alternate Kit Projects

Requirement 3 b can be met by a kit project. The kit suppliers listed at the back of this pamphlet have a number of digital kits. These include digital clocks, stopwatches, thermometers, and calculators. However, these may cost more than you are willing to pay. You should examine the cost factor closely before deciding on a kit.

Figure 66

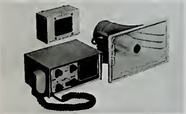


Figure 67

Figure 68

Audio

Audio is one of the most enjoyable fields in electronics. It deals with frequencies that are within the range of the human ear. Devices such as record players, PA systems, and electronic musical instruments are classified as audio equipment.

What Is Audio? When we strike the middle C key on a piano, the sound we hear is caused by a vibrating wire. The wire vibrates about 260 times each second. This, in turn, causes the molecules in the air to vibrate at the same rate. A mild shock wave of air is produced and travels out in all directions.

When this shock wave reaches us, our eardrums vibrate at the same frequency. As a result, we hear a pleasing tone. The tone we hear has the same frequency as that produced at the piano.

For middle C the frequency is about 260 cycles per second or 260 Hertz (Hz). The lowest note on the piano is about 27 Hz. The highest is over 4,000 Hz. Most people can hear both extremes without any trouble. In fact, a good ear can hear frequencies between 15 Hz and 20,000 Hz. These extremes are considered to be the limits of the audio-frequency range. Audio equipment is used to produce, record, amplify, or reproduce frequencies in this range.

Audio Equipment

Most audio equipment can be placed in one of three categories.

Figure 72

Figure 73

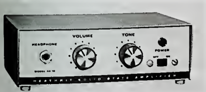


Figure 74

The largest is the "hi-fi stereo" field. This includes record players, tape recorders, etc. The purpose of this equipment is to entertain. A good hi-fi system (Figure 66) will faithfully reproduce any sound within the audio range. That is, it may have a frequency response from 15 Hz to 20,000 Hz.

Another audio field is concerned more with the spoken word than with music. Public address systems (Figure 67) and intercoms fall in this category. The human voice covers a narrow frequency range (about 100 Hz to 3000 Hz). Consequently, the frequency response of such systems need not cover the entire audio range.

A final category is that of electronic musical instruments. Electronic organs (Figure 68) and electric guitars are examples. These instruments produce a wide range of frequencies. In addition, they can create special effects.

Alternate Kit Projects

Low-cost electronic kits are available which will satisfy requirement 3c. Kit suppliers are listed at the end of the pamphlet.

If you are interested in code, you might consider a code practice oscillator (Figure 72).

Those who are musically inclined might prefer an electronic metronome shown in Figure 73.

If you prefer to listen to music rather than play it, you could build an audio amplifer. An amplifier is used to increase the signal strength to the level necessary for driving a loudspeaker. A low-cost single-channel amplifier (Heathkit model AA-18) is shown in Figure 74.

Electronic Siren Project

A simple example of an audio device is the electronic siren like the one in Figure 69. It produces a sound like that of a wailing police siren. The frequency of the wail slowly increases as a pushbutton is held down. Once the pushbutton is released, the frequency of the wail slowly decreases.

Circuit Operation. The schematic diagram for the electronic siren is shown in Figure 70.

When switch S_1 is closed, capacitor C_1 begins to charge. As it does so, it makes the base of Q_1 more and more positive. This slowly turns Q_1 on. Current through Q_1 turns Q_2 on. Q_1 and Q_2 form a direct-coupled amplifier.

Part of the output from Q_2 is applied to the input of Q_1 through capacitor C_2. This provides the regenerative feedback that causes the circuit to oscillate. When switch S_1 is opened, C_1 discharges through R_2 and the base of Q_1. The "wailing rate" of the siren can be changed by substituting different values of R_1 and C_1. An increase in the value of R_1 or C_1 lengthens the rate at which the frequency of oscillation increases.

Battery drain with switch S_1 open is only about 400 microamperes. Therefore, power switch S_2 is not necessary. But such a switch

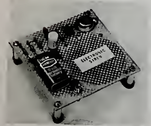


Figure 69

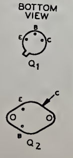
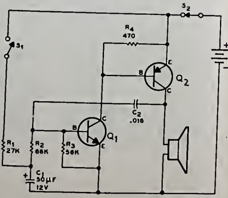


Figure 70



will add to battery life.

Construction. Good results can be obtained by building the circuit on perforated board as shown in Figure 71. All components except the speaker mount on top of the board.

Parts List

C_1 =	50 microfarads, 12 volts, electrolytic
C_2 =	0.018 microfarad, 25 volts or greater
Q_1 =	transistor, RCA SK3020 or GE-20
Q_2 =	transistor, RCA SK3009 or GE-3
R_1 =	27K, ½ watt, 10%
R_2 =	68K, ½ watt, 10%
R_3 =	56K, ½ watt, 10%

The drawing shows all wiring connections as viewed from the bottom of the board. The completed unit can be placed in a plastic box, or the board can simply be supported by standoffs and rubber feet as shown.

R_4 =	470 ohms, ½ watt, 10%
S_1 =	switch, single-pole push-button
S_2 =	switch, single-pole single throw

speaker = 3.2 ohms to 8 ohms
battery = 9-volt transistor radio type
set of battery clips
perforated board
terminal posts (optional)

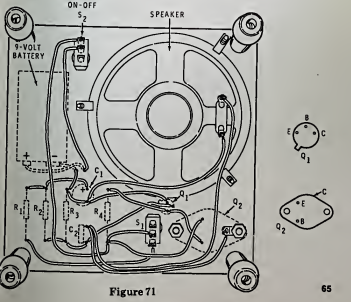


Figure 71

Test Equipment

Test equipment includes the instruments which are used to diagnose the operation of electronic circuits. The most popular types of test equipment are meters, oscilloscopes, and signal generators.

Meter Movement. In electronics, meters are used to measure current, voltage, and resistance. The heart of any meter is the meter movement (Figure 75). The meter movement consists of a coil of fine wire wound on a light aluminum frame. The frame is suspended free to rotate. The coil has leads attached so that current can be forced through it. The coil is suspended in the field of a permanent magnet.

When current flows through the coil, a magnetic field develops around it. This field interacts with the field of the permanent magnet. The interaction of the two fields causes the coil assembly to rotate. A pointer is attached to the coil. As the coil rotates, it moves the pointer in front of a scale. The more current that flows through the coil, the further the coil will rotate. This forces the pointer to move further up the scale.

Ammeter. A meter designed to measure current is called an ammeter. The meter movement alone can be used as an ammeter. Normally, though, a range switch is added so that the meter can measure a wide range of current. We change ranges on an ammeter by switching different values of shunts across the meter movement. (See Figure 76.) The shunts are simply small-value resistors. They detour some of the current around the meter movement.

An ammeter is delicate and can be easily damaged. It must be connected to the circuit so that the current to be measured flows through the meter. For this reason, the circuit under test must be broken to insert the ammeter.

Voltmeter. If the meter is designed to measure voltage, it is called a voltmeter. The voltmeter uses the same type of meter movement as the ammeter. The voltmeter is connected across the voltage to be measured. The circuit under test need not be broken or interfered with in any way. (See Figure 77.)

A low voltage can be applied directly to the meter movement. However, a higher voltage might cause a high enough current to burn out the delicate coil. For this reason, a large-value resistor is connected in series with the meter movement. This resistor limits the amount of current flowing through the coil. The range of the voltmeter is changed by switching different values of resistors in series with the meter movement. On a given range, the current that flows through the meter is determined by the voltage across which the leads are connected. The meter scale can be marked off in volts.

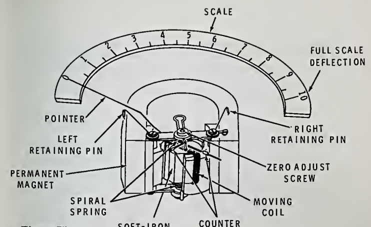
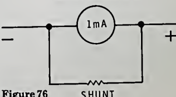


Figure 75



A

Figure 76

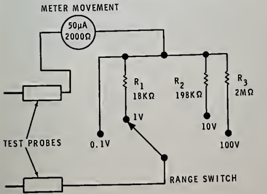


Figure 77

Ohmmeter. The ohmmeter (Figure 78) is used to measure resistance. It consists of a meter movement and a battery connected together. The resistance to be measured is connected across the ohmmeter leads. The battery forces a current through the resistance and through the meter movement. The amount of current depends on the resistance value under test. The meter scale can be marked off in ohms.

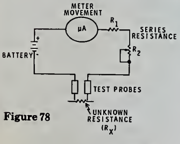


Figure 78

Multimeter. As you have seen, all three types of meters used the same type of meter movement. (See Figure 79.) For this reason, the ammeter, the voltmeter, and the ohmmeter are generally combined in a single instrument. This instrument is called a multimeter. A switch is used to change the meter movement from one function to the next. The multimeter is the most common piece of test

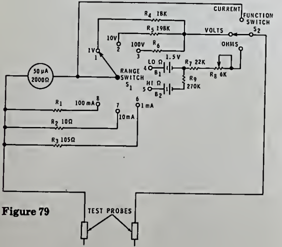


Figure 79

equipment used in electronics work. (See Figure 80A)

Digital versions of the multimeter are becoming increasingly popular. With the digital multimeter, the values of voltage, current, or resistance are displayed as numbers. (Figure 80B.)

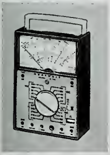


Figure 80A

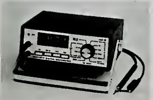


Figure 80B

Oscilloscope. Another useful piece of test equipment is the oscilloscope (Figure 81). This instrument has a screen like that of a small television set. However, the oscilloscope screen is used for viewing voltage wave shapes rather than TV programs. It shows how the voltage in a circuit changes with time.

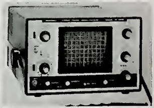


Figure 81

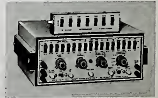


Figure 82

Signal Generators. Many different types of signal generators are used in electronics. The most common are those used to diagnose and align radio and TV receivers (Figure 82). These signal generators act as tiny replicas of the transmitting stations. They allow us to inject the proper type of signal at various points throughout the radio or TV circuit. For this reason the signal generator is a valuable trouble-shooting aid.

Careers in Electronics

In a general way, the electronics industry is divided into five areas: manufacturing, engineering, merchandising, operating, and servicing or maintenance. Each of these is subdivided further into more specific sections. Many kinds of jobs are available in each of these areas.

Some of these jobs you can handle without any special training. You learn on the job. Many companies offer what is called on-the-job training with pay. Such a position is well worth going after, because you stand a good chance of becoming an expert in your line. Add a little vocational school education, and you really can go places.

Types of Jobs

In *manufacturing*, there are two separate fields. Most manufacturing jobs are in the factory. The second group is in the field in contact with the public (customers).

Then there is *electronics engineering*. Here highly-trained people, preferably college-educated, are in most demand. But a good technician can get along fine.

If you are a radio ham or interested in electronics, you may not want a *sales* job. However, with technical knowledge you can often do well in sales.

Many types of electronics equipment are so specialized that a trained *operator* is required. Some examples include satellite tracking equipment, TV cameras, computers, and ship radios. Frequently the operator must maintain and repair his own equipment.

In all fields of electronics, *service* and *maintenance* people are required. Any electronic device can fail from time to time. It must be quickly and expertly repaired and service technicians are needed.

Typical Positions. As an *engineer*, you might find yourself designing electronic equipment or large electronic systems. Most engineers have degrees, but there are many nondegree engineers.

Technology moves so rapidly that the engineer must constantly update his education. New components and techniques are introduced daily.

The *technician* can have a variety of jobs. He may be required to turn engineering ideas into hardware, to repair equipment, to calibrate test instruments, etc. Most technicians have 1 or 2 years of technical education beyond high school. Many receive their training in the military. Others go to vocational schools or junior colleges. Some receive on-the-job training or study at home by correspondence.

Some technicians start as *assemblers* and work their way up. The assembler works in the factory, building electronic equipment. He should have a high school diploma and mechanical aptitude.

Learning More About Electronics

Scout Literature

The following may be ordered through your Scout distributor or your local Scout service center or from the Boy Scouts of America, North Brunswick, N.J. 08902.

Radio and *Signaling* merit badge pamphlets

Shortwave Listening, *Boys' Life* reprint, No. 26-091.

American Radio Relay League Publications

The amateur radio operators' national organization has several books of interest. The books are available in local radio-parts stores or from the League at Newington, Conn. 06111.

A Course in Radio Fundamentals

Twenty-six chapters present the electronics principles that are basic to understanding radio circuit operation.

Let's Talk Transistors

Starts with elementary atomic theory, goes on through *holes* and *electrons*, through PN junctions to practical circuits; 40 pages.

Here's Ham Radio

Contains information on how to become an amateur radio operator. Includes a cassette tape to assist you in learning the code.

The Radio Amateur's Handbook

The standard how-to-do-it manual for home construction and design of radio equipment.

Understanding Amateur Radio

Thorough but easy-to-read text telling how radio works, with charts and tables. It also contains construction details for transmitters and receivers.

Books

A complete line of electronics books for hobbyists and experimenters is available from:

Hayden Book Co., Inc.
50 Essex St.
Rochelle Park, N. J. 07662

Howard W. Sams & Co., Inc.
4300 West 62nd St.
Indianapolis, Ind. 46206

TAB Books
Blue Ridge Summit, Pa. 17214

Magazines

Radio-Electronics. Published by Gernsback Publications, Inc., 200 Park Ave. South, New York, N. Y. 10003. It contains construction projects and articles of general interest.

QST. Official magazine of the hams' national society, the American Radio Relay League, Newington, Conn. 06111. Subscription is included in membership dues.
Popular Electronics. Published by Ziff-Davis Publishing Co., 1 Park Ave., New York, N.Y. 10016. It contains fresh ideas for the beginning electronics experimenter.
Ham Radio. Published monthly by Communications Technology, Inc., Greenville, N.H. 03048. It contains solid-state construction projects, mainly in radio but sometimes in other areas of electronics.
Elementary Electronics. Published monthly by Davis Publications, Inc., 229 Park Ave. South, New York, N.Y. 10003. It contains construction projects and articles for the hobbyist and experimenter.

Educational Programs

Short, concise, and inexpensive individual learning programs in electronics are available from:
Heathkit Continuing Education
Benton Harbor, Mich. 49022
Westinghouse Learning Press
770 Lucerne Way
Sunnyvale, Calif. 94086

Sources of Parts and Kits

Electronic parts and kits can be ordered from a number of mail-order companies. A partial list is given below. You should write to these companies for their latest catalog.
For information on parts write to:
Allied Electronics Sorp.
2400 Washington Blvd.
Chicago, Ill. 60612
*Lafayette Radio Electronics
111 Jerico Turnpike
Syosset, L.I., N.Y. 11791
Olson Electronics
260 South Forge St.
Akron, Ohio 44327
Poly Paks, Inc.
16 Del Carmine St.
Wakefield, Mass. 01880
*Radio Shack
Parts Department
One Tandy Center
Fort Worth, Tex. 76102
For information on kits write to:
EICO
283 Malta St.
Brooklyn, N.Y. 11207
*Heathkit
Benton Harbor, Mich. 49022
MITS
6328 Linn N.E.
Albuquerque, N. Mex. 87108
*Radio Shack
Parts Department
One Tandy Center
Fort Worth, Tex. 76102
Southwest Technical Products Corp.
Box 32040
San Antonio, Tex. 78284
*These companies have local stores in many metropolitan areas. Check your local phone directory. In addition, most cities have local electronics distributors. Look in the Yellow Pages of your phone book for distributors in your area.

MERIT BADGE LIBRARY

Though intended as an aid to Boy Scouts and Explorers in meeting merit badge requirements, these pamphlets are of general interest and are made available by many schools and public libraries. The latest revision date of each, which may not necessarily correspond to the copyright date of the pamphlet, is shown below (corrected to June 1, 1981).

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3395	Animal Science	1975
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3350	Journalism	1978
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3389	Law	1975
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3278	Lifesaving	1980
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3289	Metals Engineering	1972
3312	Metalwork	1969
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3294	Motorboating	1962
3338	Music and Bugling	1968
3285	Nature	1973
3306	Oceanography	1965
3385	Orienteering	1974
3372	Painting	1973
3286	Personal Fitness	1971
3270	Personal Management	1972
3281	Pets	1989
3334	Photography	1971
3382	Pioneering	1974
3398	Plant Science	1975
3388	Plumbing	1965
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3377	Printing	1985
3251	Public Health	1989
3373	Public Speaking	1989
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3322	Sculpture	1969
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3250	Skating	1973
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3328	Theater	1968
3391	Traffic Safety	1975
3371	Truck Transportation	1973
3281	Veterinary Science	1973
3357	Water Skiing	1969
3274	Weather	1963
3265	Wilderness Survival	1974
3315	Wood Carving	196[illegible]
3318	Woodwork	197[illegible]

Merit badge pamphlets are also available in library-bound editions. For complete information write the Supply Division.

BOY SCOUTS OF AMERICA • SUPPLY DIVISION

MIDWESTERN DISTRIBUTION CENTER
1930 N. Mannheim Road
Melrose Park, Ill. 60160

WESTERN DISTRIBUTION CENTER
120 San Gabriel Drive
P.O. Box 556
Sunnyvale, Calif. 94086

EASTERN DISTRIBUTION CENTER
2109 Westinghouse Boulevard
P.O. Box 7143
Charlotte, N.C. 28217

New England Scout Shop—Highland Plaza, Needham Heights, Mass.
Chicago Scout Shop—128-30 South Franklin Street
New York Scout Shop—308 Fifth Avenue
San Francisco Scout Shop—731 Market Street